pital type arcs applicable to institutional treatments are large enough to give therapeutic quantities of radiation over entire hospital wards so that large groups can be treated at once from one lamp, but they require special wiring.

The electrodes in carbon arc lamps may be solid carbons or may be carbon tubes impregnated with various metals. In Europe pure metal electrodes, like tungsten or iron, are also employed. The lamps may be equipped with single, double or four pairs of electrodes. The multiple electrode type prevents waste of current and, when suitably arranged, permits the treatment of several people placed in a circle around or underneath the lamp. Solarium types of both mercury vapor and carbon arc lamps have been found useful in large institutions for group irradiation.

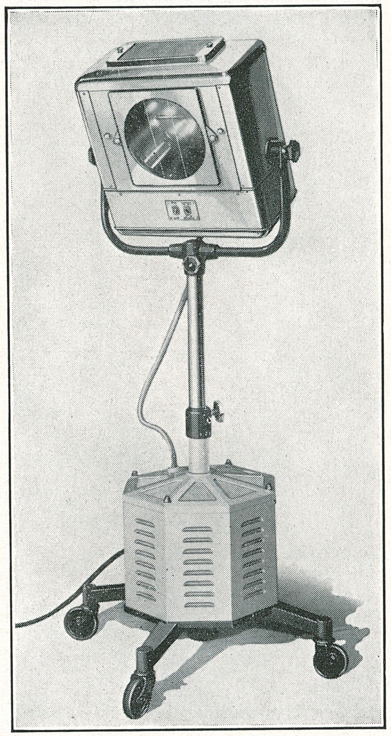


Fig. 230.—Carbon arc lamp. (Courtesy National Carbon Co.)

A proper balance between the strength of the current and the size of the carbons is essential for efficient radiation.

In using carbon arc lamps on direct current the temperature of the electrode at lower potential (called the positive electrode) is raised considerably higher than in the negative electrode. The crater forms at the end of the positive electrode, and thus it burns up quickly. With the alternating current the consumption of carbons is equal on both ends.

Radiation Characteristics.—The radiation of arc lamps is emitted from two sources. (1) The glowing ends of the electrodes are very hot. These tips emit radiation the same as any other incandescent body. Spectral analysis shows that this radiation has a continuous spectrum with all

wave lengths present. (2) The arc stream itself or the path of the current through the gap between the ends of the electrodes is much more important. It is the source of most of the radiation from the carbon arc. Its spectral analysis shows a line or band spectrum consisting of lines or bands of definite wave lengths. This radiation comes from the vapors of the metals being melted and volatilized at the ends of the electrodes. In the case of iron and other heavy metals, this radiation from the arc stream consists of a multitude of lines so closely spaced that unless a powerful spectroscope is used the radiation appears to be continuous. Different metals give different kinds of radiation and the kind desired can be obtained by selecting the proper type of electrode.

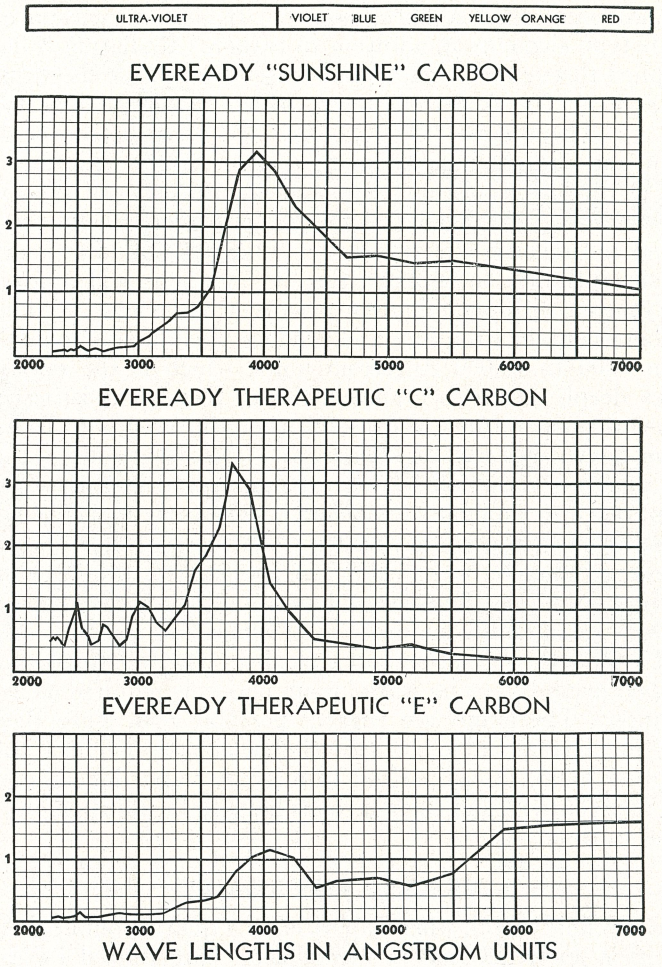


Fig. 231.—Radiation characteristics of therapeutic carbons. (Courtesy of the National Carbon Company.)

The carbon arc furnishes a radiation more nearly like sunlight, with the following differences: there are more shorter rays present in the ultraviolet zone than in the sun, there is less luminous radiation and a more intense infrared emission present. (See Frontispiece.)

The intensity and quality of radiation from carbon arcs depends on (1) the kind of carbons and their size, (2) the direction of current when direct current is employed, and (3) the amount of current employed. It is important that the various kinds of carbons be employed in suitable lamps because the efficiency of output depends on the correct proportion between voltage, amperage and the diameter of the carbons.

There are three types of carbons available at present: (1) the *sunshine* type of carbon furnishes an artificial source of radiation more nearly like sunlight than any other artificial source. It contains cerium and other rare earth type elements in addition to carbon. Radiation from this arc when applied through a Corex D glass screen furnishes a spectrum ranging from 2900 to 40,000 Angstrom units, which is very similar to outdoor sunlight. (2) Therapeutic "C" carbons. "*C*" type carbons contain iron, aluminum and nickel, in addition to carbon. Arcs with this type are designed to produce a maximum amount of ultraviolet of the short-wave region from 2000 A. U. to 3100 A.U. These regions chiefly produce erythema and antirachitic effects. In the untanned skin of an individual of average susceptibility to sunburn the "C" carbons will produce a first degree erythema with one minute exposure at 36 inches. (3) Therapeutic "E" carbons contain strontium and produce maximum amounts of radiation from 7000 to 10,000 Angstrom units, which is the radiation that penetrates deeply into subcutaneous tissue, thereby assisting in raising subcutaneous temperatures, and useful where infrared is to be applied.

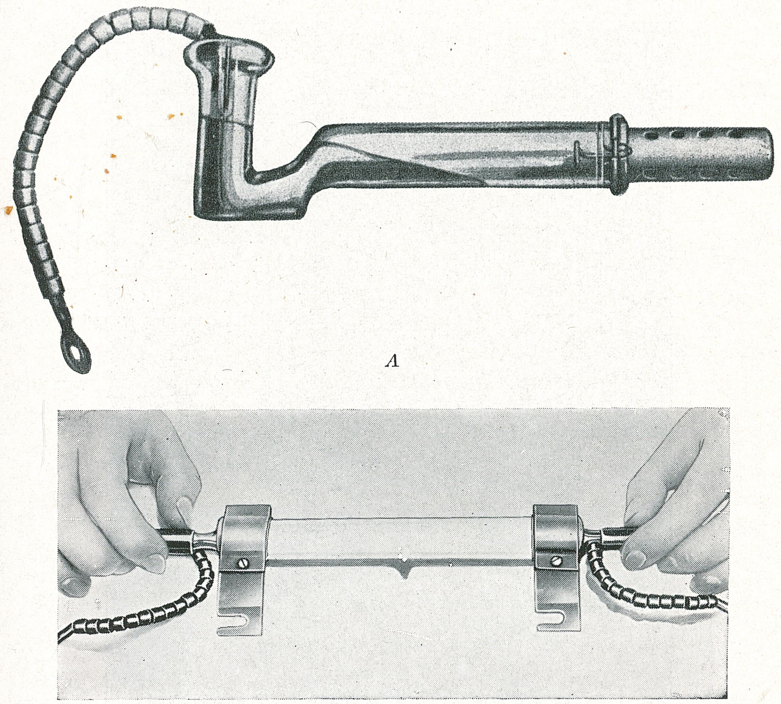
Relative Advantages and Disadvantages.—The carbon arc is the hottest artificial source of radiation readily obtainable and in this respect is the closest approach to sunlight. (Coblentz.[6]) The early makes of carbon arc lamps employed in the United States were unsatisfactory, because their radiant energy emission was weak. The arcs sputtered on account of the current fluctuation and unpleasant fumes and ashes were produced. In the newer types of lamps the problem of fumes and sparks is solved by a perfected system of ventilation and screening. The full power of the lamp is developed instantly, so no warming-up period is required as in mercury vapor lamps. The lamps are rugged, portable and, since they consist chiefly of metal, reasonable mechanical shocks have no effect upon them. On the other hand, in comparison to mercury vapor lamps, carbon arcs consume more current and their carbons have to be adjusted and replaced from time to time.

MERCURY VAPOR LAMPS

Mercury, a fluid metal, when vaporized in a quartz container by intense heat, emits a spectrum rich in ultraviolet, characterized by a series of intense spectral lines or bands. All electric discharges in mercury vapor produce the mercury spectrum, which is the same, provided the lamp has an envelope of fused quartz. Quartz or silicon dioxide glass is extremely heat resistant and at the same time freely transmits ultraviolet. Ultraviolet lamps, which have an outer jacket of glass or employ a glass envelope instead of quartz, have a spectrum of mercury restricted by the transmission characteristics of the glass. The wave length and flux intensity of these spectral bands vary according to the construction of the generator.

The mercury vapor pressure in lamps is determined by the temperature and may fall within three groups: (1) High pressure of the order of 1 to 10 atmospheres, in hot quartz lamps (2) medium pressure, of the order of 0.1 atmosphere, in moderately warm lamps and (3) low pressure, of the order of 0.001 atmosphere, in cold quartz lamps.

Hot Quartz Lamps.—The principal part of the hot quartz vapor lamps is the "burner," a fused quartz tube, exhausted of air and containing mercury. Suitable attachments conduct an electric current to the burner, which is housed in an adjustable chromium reflector. Present types of hot quartz burners usually consist of "activated" tubes filled with argon gas and just a small amount of mercury. They light up without tilting as soon as the current is turned on and emit, after a few minutes, radiation at full strength. Older types of burners contain a pool of mercury at either end, or one mercury pool at the negative end (cathode) and a tungsten rod at the positive end (anode). After turning on the current, the burner is tilted as the mercury runs across the vacuum, completing the circuit, and then becomes gradually vaporized by the heat. In contrast to the carbon arc lamps and the newer mercury lamps, the arc of which is struck at nearly full intensity as soon as the lamp begins to function, the older mercury vapor arc lamps require about ten minutes to "build up" so that treatment must not be started earlier.


A

B

Fig. 232.—*A*, Older type tungsten-mercury burner. *B*, Quartz burner with activated electrode (Courtesy of the Hanovia Chemical and Manufacturing Company.)

The emission of the hot quartz mercury lamp contains very little short infrared radiation, a fairly large amount of the violet end of the visible spectrum and a large amount of ultraviolet. The spectrogram of the mercury arc consists of a series of spectral lines superimposed on a faint continuous spectrum. (*See* colored frontispiece). The quartz tube and the hood emit a small amount of long wave infrared radiation. In the high pressure mercury spectrum, there are twelve principal wavelengths which have about 80 per cent of the radiant ultraviolet energy and very many lesser wavelengths, which share the remaining 20 per cent of energy. The wavelength at 2537 A. has only 9 per cent of the energy. The other principal wavelengths are at 2482, 2652, 2700, 2752, 2803, 2894, 2967, 3025, 3130, 3341, and 3660 angstroms. By their nature, high pressure lamps can be made at higher wattages and, therefore, at higher intensities than any of the other types (because the others have to be kept colder and increasing electric power would heat them up and alter their characteristics.) For this reason, and because their radiant energy is more uniformly spread throughout the ultraviolet spectrum, high pressure mercury lamps, such as the "hot quartz" have found favor in research and in clinical applications.

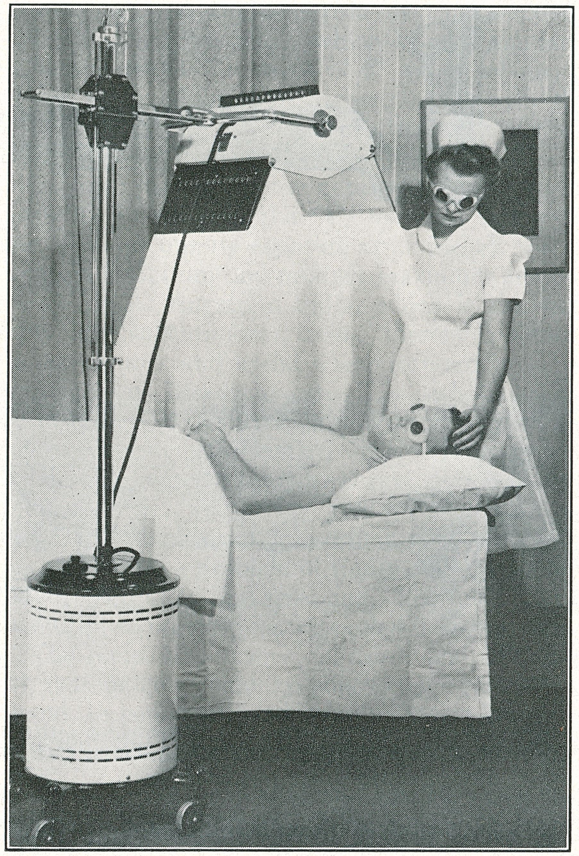


FIG. 233.—Mercury vapor lamp. (Courtesy Hanovia Chemical and Mfg. Co.)

The emission of the hot quartz mercury lamp contains very little short infrared radiation, a fairly large amount of the violet end of the visible spectrum and a large amount of ultraviolet; about 6 per cent of the total radiation is of wave lengths shorter than 2900 Angstroms, entirely absent in sunlight. There is considerable difference between this type of radiation and that of the sun. The spectrogram of the mercury arc consists of a series of spectral lines superimposed on a faint continuous spectrum. (See Frontispiece.) The quartz tube and the hood emit a low temperature, long-wave radiation.

Quartz burners slowly deteriorate with use, due to the fact that the quartz tube decreases in transparency and does not transmit as much of the light as before. The decrease of intensity affects all portions of the spectrum in nearly equal measure. The greatest decrease occurs during the first hundred hours of operation and it is estimated that after that period the ultraviolet intensity is about 80 per cent of the original one. After one thousand hours the total intensity of radiation is from two-thirds to one-half of the lamps when new, provided that the lamps operate on the same voltage and amperage. Erythema tests should be applied periodically to check up efficiency of the burner. The ultraviolet energy output can also be physically measured from time to time.

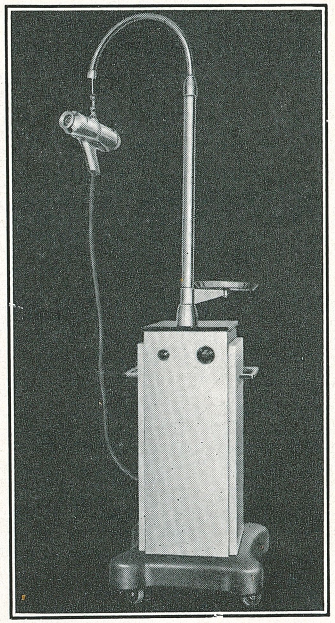


FIG. 234.—Air-cooled local mercury vapor lamp. (Aero-Kromeyer). (Courtesy of Hanovia Chemical and Manufacturing Company.)

The burners and lamps illustrated heretofore serve chiefly for general irradiation and being kept at a considerable distance from the body, the air circulating under their hood is sufficient to keep the burners from overheating; hence their designation as "air-cooled" lamps. Special mercury vapor lamps, specially designed for local treatment have been earlier known as "water-cooled" or Kromeyer lamps. In these the burner is surrounded by a water jacket with inflow and outflow tubes for cold water and has a quartz window at one side for the transmission of radiation from which the heat rays have been absorbed. These somewhat cumbersome and expensive lamps have been recently superseded by an air-cooled local ultraviolet lamp (Aero-Kromeyer), which eliminates the water-circulation system; it enables exposure of an area approximately 1½ inches in diameter at close approximation. Suitably shaped quartz rods can be attached to the "windows" of both forms of lamps, enabling the conduction of the rays inside of any mucous orifice, sinus or sluggishly healing wound cavity. Ultraviolet radiation will travel along these rods even when they are bent at an angle and then pass out at the end in a direct beam. It does not radiate along the sides of the rods.

The simplicity of handling and upkeep has made the hot quartz lamps the most widely used source of artificial light. They require comparatively little current; any other source of ultraviolet energy can produce the same intensity of radiation only by the expenditure of four or more times the electrical energy. With suitable "filters" various parts of their spectral emissions can be utilized. (Figs. 209 and 235.)

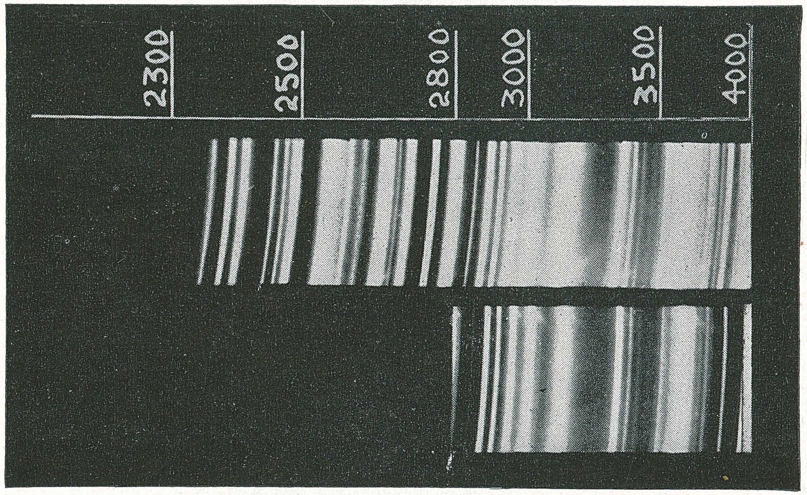


Fig. 235.—Spectrum of quartz mercury arc through Corex-D glass. Upper photograph shows full spectrum; lower shows only radiation of longer wave lengths than 2800 A, all short waves having been filtered out.

Electrodeless Induction Lamps.—These lamps are medium pressure mercury vapor lamps, consisting of an evacuated round bulb of quartz of Corex D glass, containing a tiny drop of mercury surrounded by a high-frequency coil connected to the transformer of a long or short-wave diathermy machine. The surrounding high voltage circuit brings the mercury vapor in the bulb to luminescence within thirty seconds of starting the current. In the radiation emitted, about 30 per cent of the ultraviolet is concentrated in the wavelength at 2537 anstroms, and other wavelengths, notably those at 2967, 3130 and 3660 angstroms, have also effective quantities of radiation. A typical medium pressure lamp is the high frequency electric current quartz induction lamp. Its emission is similar but less powerful than that of the hot mercury lamp. During treatment the bulb remains comparatively cool and it is claimed that it retains its transparency to ultraviolet radiation in contrast to the gradual clouding of the hot quartz burners. The fact that there are no seals or electrodes protects the burner against loss of its vacuum.

Electrodeless quartz lamps can be furnished in the form of a general body lamp as illustrated, and in the form of a hand lamp for local application. The mounting of miniature quartz bulbs on the end of wired catheter tubes, enables the insertion of these sources of radiation into practically every orifice and cavity of the body, kidney, colon and stomach.

The combination of this lamp with a high-frequency apparatus enables saving of space in small offices. Some long-wave and short-wave diathermy units have been equipped with circuits to energize such electrodeless ultraviolet lamps.

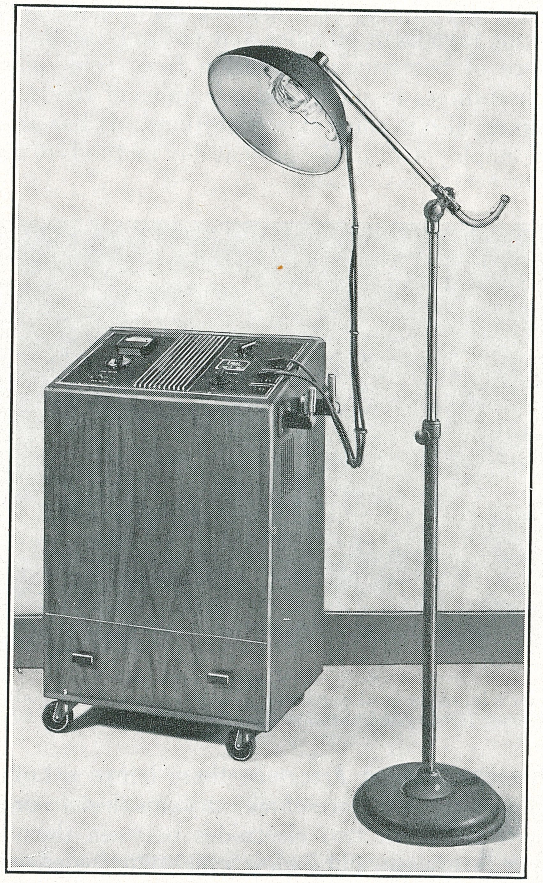


Fig. 236.—Electrodeless induction lamp, energized by short-wave diathermy machine. (Courtesy of the Lepel High Frequency Laboratories.)

Cold Quartz Lamps.—In these lamps a narrow quartz tube containing mercury and neon gas, resembling the old time Geissler tube, becomes illuminated by an electrical current of high voltage. A transformer steps up the alternating current supply to about 2500 volts; the amperage and vapor pressure in the glow tube is very low; there is very little current consumption and consequently the tube remains cold and can be readily approached to the body or inserted in orifices. The full energy emission of these lamps is present within a minute and it remains extremely constant.

The spectral emission of cold quartz lamps consists of about 95 per cent in the line of 2537, in the short ultraviolet field. (See Frontispiece.) This ultraviolet band has enough penetrating power through the epidermis to cause biological and therapeutic effects; it also is antirachitic in rats, as are all radiations around 2500 Angstrom units. It produces erythema without much pigmentation or blistering. (Bachem.[3])

Cold quartz lamp generators come in two models: general body radiation lamps consisting of quartz tube in the form of a hexagonal grid mounted on a large aluminum reflector and supported on a stand and an orificial lamp, consisting of a holder of variously shaped rods for introduction in body orifices—such as the mouth, vagina, urethra and rectum. These orificial tubes emit rays from all sides and not only at their tip.

The prevalence of bactericidal radiation from cold quartz generators points to their usefulness in superficial infections of the skin as well as of mucous membranes; also in some skin conditions. It has also lead to their almost exclusive employment in the present day methods of air disinfection.

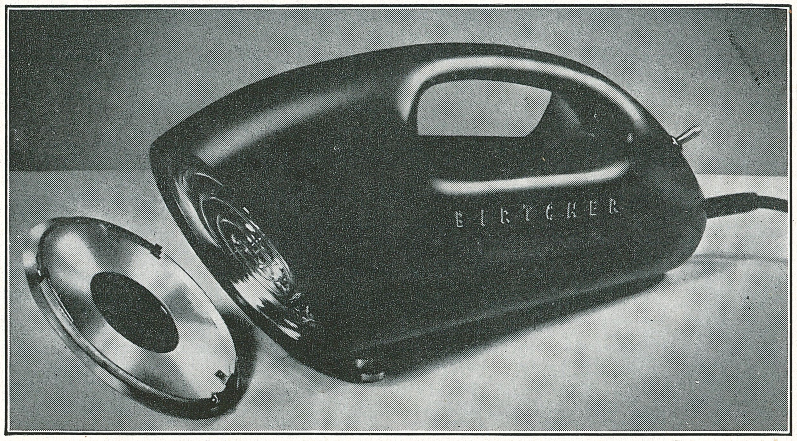


Fig. 237.—Cold quartz lamp for local application. Equipped with a Wood's Filter, it enables fluorescent (black light) examination. (Courtesy of the Birtcher Corporation.)

Other Low Pressure Mercury Arcs.—In these lamps a bulb of quartz or other special glass contains a trace of mercury; an electric circuit heats up a tungsten filament and then two electrodes between them which an arc of mercury vapor forms, causing a glow which fills the entire bulb. These lamps come in two general types.

The Thin Window Mercury Glow Lamp.—In a glass bulb an indrawn thin bubble forms an extremely thin window which permits the passage of ultraviolet radiation down to 1800 A.U. which are not transmitted through the glass of ordinary thickness, and which are filtered out by the water in water-cooled lamps. A tungsten filament between two electrodes is heated by an independent circuit; in a few seconds a mercury arc forms between these two electrodes from the traces of mercury in the bulb. The lamp operates at 2 amperes at 16 volts and a special reactance (step-down transformer) serves to reduce the voltage of the A.C. supply current. On account of the relatively low temperature, the lamp can be brought in close approximation to the skin and serves for conditions amenable to local ultraviolet irradiation.

The relative energy distribution of the thin window lamp consists of 55 per cent ultraviolet, chiefly in the region of 2537 Angstroms, 10 per cent visible and 35 per cent infrared; the addition of this extra infrared is the only difference from the cold quartz units. The author[17] has made extensive clinical tests with this lamp and found that in the average skin an application for five minutes of close contact causes an erythema lasting five to ten days, which does not result in either peeling or blistering. A ten minute exposure is followed only by slight pigmentation. Laboratory studies show that it is possible to get a sterile culture from the surface of the skin after five minutes exposure. Clinical results were reported with the thin window lamp by the author and others in: (1) pyogenic infections of the skin; (2) fungous and parasitic affections of the skin, and (3) sluggish ulcers and wounds.

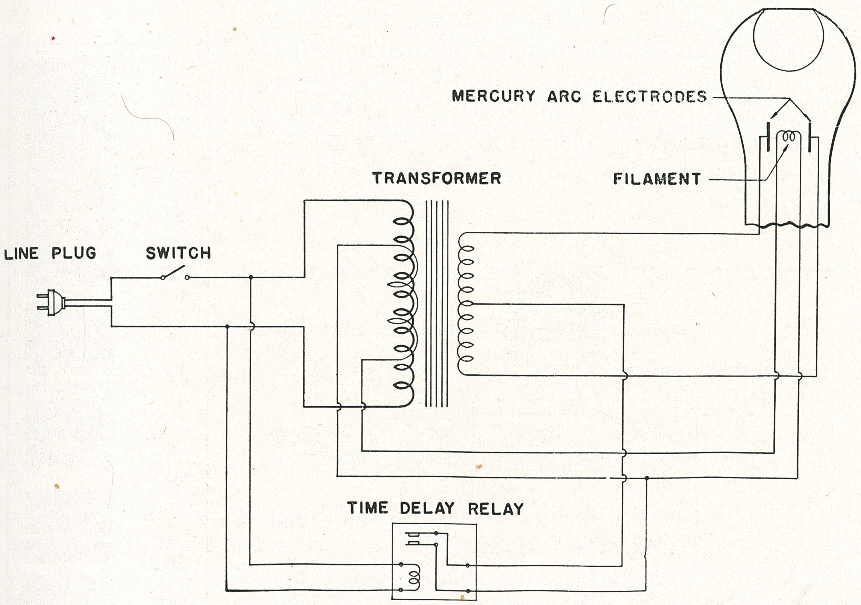


Fig. 238.—Diagram of thin-window lamp. (Courtesy of the Westinghouse X-Ray Corp.)

The Mazda Sunlight Lamps consist of an ultraviolet transmitting Corex D or quartz bulb similar in shape to the ordinary electric light bulb which contains a tungsten filament of V-shape and on top of this two tungsten electrodes. There is a drop of mercury in the bulb and after the heating of the filament the vaporized mercury forms an arc between the tungsten electrodes.

The emission from the bulb is a combination of incandescent solid (tungsten) radiation from 3650 Angstroms throughout the visible and short infrared and mercury vapor radiation with strong lines between 2800 and 4050 Angstroms. The Corex D bulb absorbs all ultraviolet radiations shorter than 2800 Angstroms which are not present in sunlight. These lamps serve principally for home use as a source of radiation similar to sunlight. They come in two sizes: the S-1 type tulb at a distance of 30 inches produces the same ultraviolet effectiveness as midday, midsummer sunlight, while the smaller S-2 type bulb has the same effect at 24 inches. Ten to fifteen minutes exposure at these distances will mildly sunburn the average person.

The bulbs of these lamps do not operate directly on the house current, but must be placed in a special fixture with a transformer; for this reason they are activated only by an alternating current supply. They are useful devices for home treatment under competent medical supervision.

R.S. (Reflector) Type Sunlamps consist of a mercury arc tube enclosed in a special glass bulb (Corex D or Corning type), opaque to short wave length ultraviolet (below 2,800 Angstroms.) Some of these lamps also contain ballast coils made of tungsten filament like in the thin window lamp which, when heated, limits the current passing through the mercury arc tube and then radiates infrared and visible light. (Fig. 240) The lamps, accepted by the Council on Physical Medicine, all emit ultraviolet radiation in accordance with the requirements for sunlamps, normally a minimum perceptible erythema in 5 minutes at 24 inches.

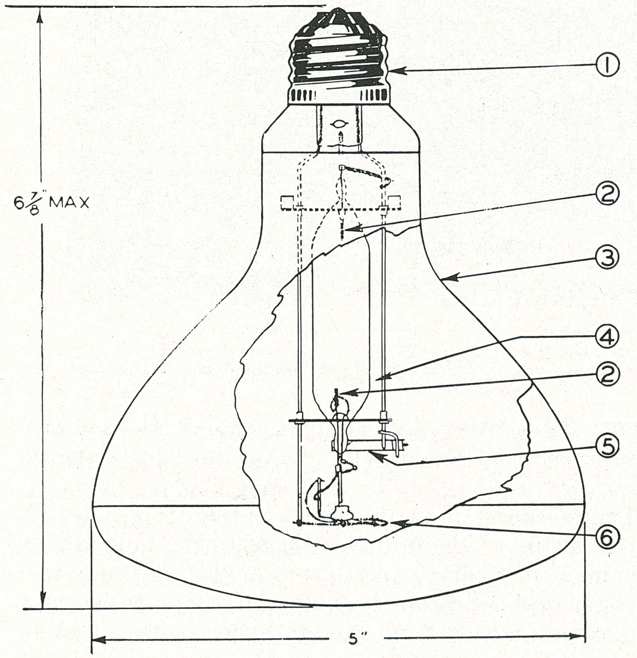


FIG. 239

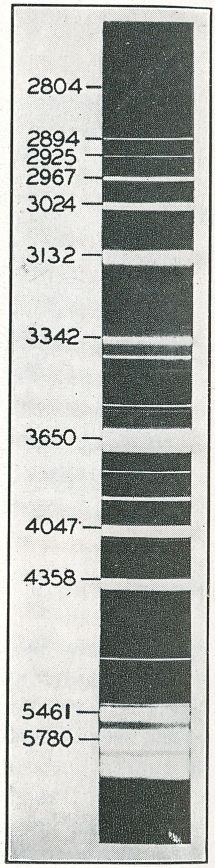


FIG. 240

FIG. 239.—Section view of RS Type Sunlamp, showing six basic elements: 1. medium screw base, 2. electrodes, in bulb, 3. special ultra violet reflecting type bulb, 4. quartz arc tube, 5. bi-metallic starting switch, and 6. tungsten filament ballast. (Courtesy of Westinghouse Electric Co.)

FIG. 240.—Spectral emission of above RS type sunlamp in the ultra violet region in addition there is also some infrared emission, generated by the tungsten filament ballast.

The chief advantage of these newer sunlamps is that they can be screwed into any 110-125 volt alternating current socket and burn in any position. They consume from 100 to 275 watts, according to their construction; some of the bulbs are partly coated with aluminum so as to form a reflector.

CHOICE OF ULTRAVIOLET GENERATORS AND STANDARDS OF EMISSION

It was pointed out repeatedly that the ideal situation would be to be able to select a radiant energy generator furnishing an efficient emission of a single wave length which has proved specific for a given pathological condition. According to present-day clinical practice, supported by the ruling of the Council on Physical Therapy[8] all generators emitting a sufficient intensity of sunburning (erythema producing) radiation are acceptable for ultraviolet therapy. Our present ultraviolet generators generally furnish combinations of the three principal groups of radiations: (1) infrared, luminous and full range of ultraviolet radiation, as represented by the modern carbon arc lamp; (2) luminous and a full range of ultraviolet radiation as represented by the hot quartz and electrodeless induction lamp; (3) an almost monochromatic radiation of short ultraviolet as represented by the cold quartz lamp, the thin window mercury glow lamp, and the air-disinfecting units. Table 45 shows the principal sources of phototherapeutic radiation and the spectral range of their emissions.

TABLE 45.—CHOICE OF ULTRAVIOLET GENERATORS

Type	*Spectral Range*	*Predominant Radiation*
Carbon arc	10,000—2700 angstroms:	Intensive infrared long and shortwave ultraviolet
Hot quartz	5,800—1850 angstroms:	Long and shortwave ultraviolet
Cold quartz lamp	2537 angstroms:	Shortwave ultraviolet

In considering the available ultraviolet generators in treatment of a specific case the first question arising is whether heat radiation in addition to ultraviolet is desirable or not. Clinical experience shows that heat in itself is beneficial in rheumatoid conditions and in joint and glandular tuberculosis; in these conditions carbon arc irradiation may be more preferable, therefore, or an infrared generator may be employed in addition to the ultraviolet source. On the other hand an excess of heat radiation is often undesirable in pulmonary or intestinal tuberculosis and in rickets, hence the preference of a radiation mainly restricted to ultraviolet in these conditions. In superficial infections of the skin and mucous membranes a generator furnishing only the shorter bactericidal range of ultraviolet radiation is preferable. The present range of generators enables a fairly wide selection according to these postulates, but there still exists need for further controlled clinical work.

Standards of Emission.—The effectiveness of ultraviolet generators is judged by the Council on Physical Therapy[8] on the basis of the erythemal reaction. The specifications of minimum intensity are based on a comfortable and convenient operating distance (24 inches, or 61 cm.) from the front edge of the reflector, at which distance the exposure can be made without burning the skin by coming in contact with the burner or by the infrared rays. The ultraviolet intensity of the lamp shall be such that the time of exposure to produce a minimum perceptible erythema (one that disappears in less than twenty-four hours) will not be longer than fifteen minutes for a therapeutic lamp and sixty minutes for so-called sun-lamps.

TABLE 46.—ERYTHEMOGENIC EQUIVALENT OF ULTRAVIOLET RADIATION REQUIRED TO PRODUCE ERYTHEMA (COBLENTZ[6])

Source	Ultraviolet intensity in microwatts per square centimeter
Sun: Midday, midsummer, midlatitude, sea level	91
Carbon arc: Blue flame, cored carbon, in reflector, no window	48
Carbon arc: Glass window, opaque to 2800 Angstroms and shorter (estimated)	90
Mercury arc: General Electric Mazda, type S-1 lamp; high temperature arc in parallel with V-shaped tungsten filament	83
Mercury arc: General Electric Mazda, type S-2 lamp; similar to the S-1 lamp, but smaller; both in glass bulbs	93
Mercury arc: Types G-1 and G-5; low temperature, low voltage thermionic glow discharge; glass bulb	108
Mercury arc: High temperature, high vapor pressure, low voltage; quartz tube	58
Mercury arc: High-frequency electrodeless discharge; quartz bulb	60
Mercury arc: Low temperature, low vapor pressure, high voltage, "cold quartz," Geissler tube discharge	36

As the emission line of the mercury arc lamp of 2967 Angstroms has the highest efficiency in generating an erythema, 100 per cent, in comparison to all other wave lengths, this line appears suited as a natural standard for evaluating sources of heterogenous ultraviolet radiation. The Council has therefore adopted 20 microwatts per square centimeter of homogenous radiation of wave lengths 2967 Angstroms as the erythemal unit (E. U.) of dosage; that is, 1 E. U. = 20 microwatts per square centimeter of radiation of wave length 2967 Angstroms.[8] For home use the Council only accepts lamps which emit practically no ultraviolet radiation shorter than 2800 Angstrom units.

For the acceptance of lamps for disinfecting purposes, the Council on Physical Medicine has adopted 100 microwatts per square centimeter of homogeneous radiation of wavelength 2,537 angstroms as the unit of germicidal intensity. The difference in effectiveness from the 2,652 band is negligible. Since the ultraviolet emission from the low vapor pressure mercury discharge tube is practically homogeneous radiation of wavelength 2,537A, such a lamp can be readily calibrated in absolute value and used as a standard.

TECHNIQUE OF ULTRAVIOLET IRRADIATION

Administration.—In general irradiation the entire unclothed body is exposed, hence the treatment room should be warm and also well aired. It is advisable to provide an individual dressing gown or sheet for each patient which covers him until the actual exposure. The eyes of the patient as well as those of the operator should be protected by goggles. Ordinary leatherette goggles can be bought cheaply by the dozen, and individual goggles provided for each patient. In case of doubt as to the effectiveness of protection, goggles should be tested for ultraviolet transmission. In patients with a sensitive skin it may be well to cover the face by a thin towel at first; the genitalia should generally be covered by a loin cloth or a folded towel. A shield cut from heavy paper may protect

the nipples. If the face is exposed it should not rest on a high support, as this would result in a more intense exposure because of the shorter distance from the lamp. (Fig. 234.)

Patients are usually treated in the recumbent position. The table or couch on which the patient rests should be a low one, allowing a ready variation of the distance from the lamp. Modern mercury and carbon arc vapor lamps now allow radiation at various angles instead of only from the horizontal or vertical position. The center part of the body should be placed in the direct line of radiation, but no old style hot quartz lamp should ever be placed directly over the patient's body.

The preliminary application of luminous heat from a large 1500-watt lamp is generally advisable, with the first few treatments with the mercury vapor lamp. Warming of the skin makes the patients feel more comfortable than if a very short exposure to the comparatively cold mercury vapor radiation is applied alone and will also accelerate the chemicobiological process following radiation. The duration of the heat radiation should be from ten to fifteen minutes and its length decreased as the length of the ultraviolet exposures is increased.

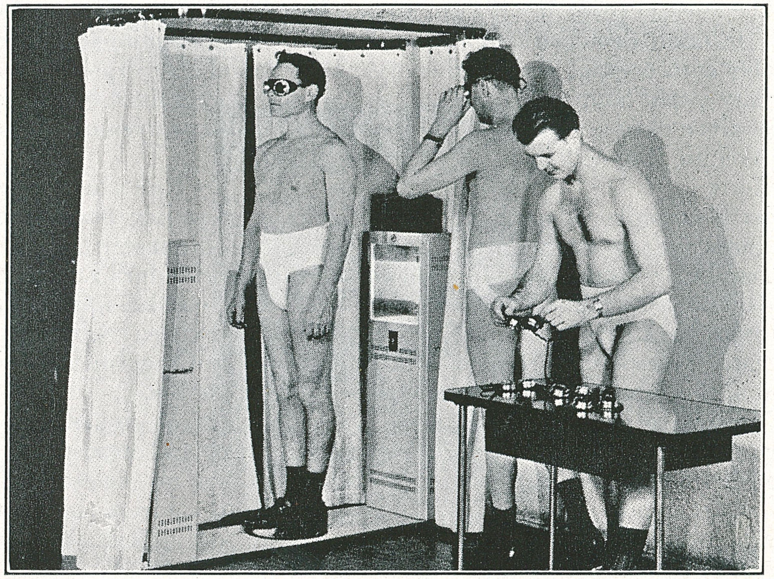


FIG. 241.—Solarium shower. (Courtesy of The Burdick Corporation)

The carbon arc lamp is ready for use as soon as it is lit and preliminary heat radiation is not necessary. With the hot mercury vapor lamp one must wait for two minutes or more according to the type of lamp, until the full output of radiation is developed. Patients experience no sensation except that of the slight warmth during treatment with the mercury arc and more intense heat when the carbon arc is used.

A time-clock should always be used to measure the time of exposure. As general radiation is usually equally divided between the front and back, the patient is instructed to turn over with the first signal and the clock is then set again for the second half of the treatment. At the end of home. The danger of over-exposure, of careless handling of apparatus and of the indefinite continuation of radiations are all valid reasons against home treatments, without the immediate and continuous supervision of a competent physician.

SPECIAL FORMS AND USES OF ULTRAVIOLET RADIATION

Ultraviolet Blood Irradiation.—Favorable reports have been made by a number of clinicians for hemo-irradiation by ultraviolet. A special apparatus of Knott serves for this procedure. It consists of a circular irradiation chamber 2 inches in diameter and 1 inch deep, against which a water-cooled-mercury quartz burner is held. Transfusion tubings are attached to two outlets from the chamber. The fomula $A = KW$ determines the amount of blood to be withdrawn, with A the amount in cubic centimeters, K a constant (1.5) and W the weight expressed in pounds. The average blood withdrawn is 225 cc. The venous blood withdrawn is citrated (1 part 2.5 per cent sodium citrate to 5 parts of blood) and immediately returned to the patient through the hemo-irradiator to the vein from which it was withdrawn. The time of exposure is considered the time required for the passage of 1 cc. blood through the chamber while exposed to ultraviolet irradiation. An automatic transfusion pump and a mechanism for controlling the flow of blood and consequently the irradiation time is part of the apparatus. It is stated that there were no harmful effects on blood cells or other untoward reactions.

The biophysical effects attributed to this procedure are: increased blood oxygen, rapid rise in opsonic index, and vasodilatation. All these should result in marked stimulation of the general resistive forces of the patient and serve as a valuable supportive measure but not as a specific therapy.

Good results are reported by Miley[24] and others in virus-like diseases, in rheumatic fever, in acute, severe infections, cellulitis, as well as in chronic infectious conditions. Patients with intractable bronchial asthma exhibited marked improvement. Rebbeck[26] also reported on successful treatment of a series of cases of puerperal sepsis and postabortional sepsis.

In spite of the spectacular results claimed for hemo-irradiation in some critically ill cases, resistant to other routine treatments, the method has not as yet found general acceptance. A critical review by Moor[25] and coworkers, corroborated the earlier finding of Hollander[44] that there was no decrease in the number of viable bacteria. They also showed that autotransfusion of irradiated blood had no effect upon the mortality time or survival in rabbits given small doses of botulin toxin. The authors conclude that their studies offer no basis of hemo-irradiation in the treatment of infections and suggest that any further clinical studies should be made with adequate means for evaluation of the procedure.

Sterilization of Blood Serum by Ultraviolet in blood banks for the prevention of infectious hepatitis has been developed in recent years by (Wolf *et al*[30] and Blanchard *et al*[4]). Relying on the inactivation of viruses by ultraviolet reported by many investigators, they used an apparatus in which a glass tube containing the serum rotates around an 18 watt cold quartz unit (Habel and Sockrider[11]). Inoculation with such serum or intradermal, intramuscular or intravenous inoculation with irradiated plasma showed no evidence of hepatitis. Hence these authors recommend the routine use of exposure to ultraviolet rays of serum and plasma under properly standardized conditions so as to prevent serum hepatitis.

Inactivation of vaccines by ultraviolet has been reported by the U. S. Public Health Service and other investigators. According to Hollander and Oliphant[14] data are now available for inactivation of five "submicroscopic" agents. Influenza virus, vaccine virus, and bacteriophage are highly sensi-

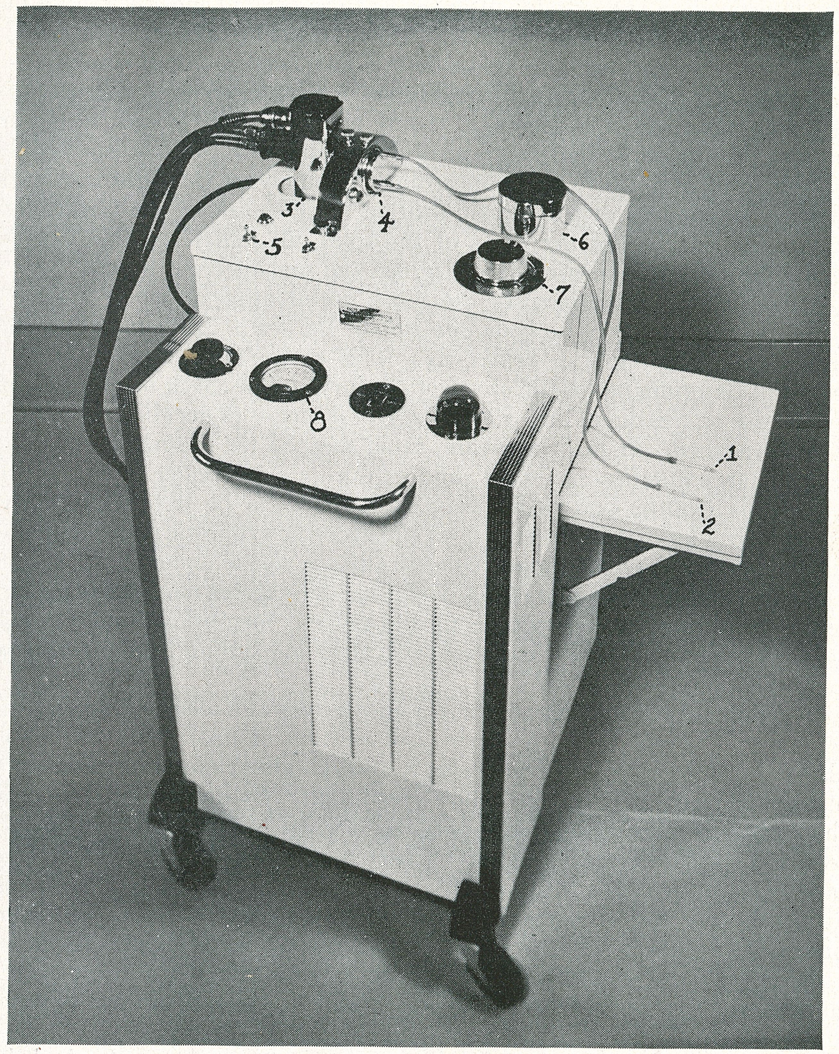


FIG. 244.—Hemo-irradiation outfit. Hemo-irradiator. *1*, glass-tipped adapter for suction or withdrawal end of rubber tubing system; *2*, glass-tipped adapter for intravenous or injection end of system fitted to needle in patient's vein. Citrated blood that has just passed through irradiation chamber (*4*) is returned to venous circulation through this adapter. *3*, water-cooled, mercury-quartz burner, source of high-intensity ultraviolet energy used in irradiating blood; *4*, Knott irradiation chamber with quartz window held in contact with mercury-quartz burner. Blood is passed through this chamber, its time of exposure being automatically adjusted. *5*, starting switch; *6*, synchronized transfusion pump; *7*, dial regulating rate of flow and time of exposure; *8*, voltmeter. (Courtesy of Dr. G. Miley.)

wavelength) may be defined in foot-watts, *i. e.*, the product of the intensity in watts per square foot in the irradiated zone and the volume of the irradiated zone in cubic feet. The intensity of a lamp at a distance of one meter has no relation to such a definition of intensity. The unit of disinfection is the lethe, and is the removal or death of E. coli by the disinfecting agent to an extent equivalent to that resulting from one air change by ventilation. The cubic foot lethe of disinfection of the air in a room by irradiation is the product of the foot-watt-minutes of irradiation, a disinfection factor and a distribution factor, and is equivalent to the same number of cubic feet of ventilation by pure air in its disinfecting effect. The disinfection factor is a constant representing the effectiveness of 2537A radiation for killing E. coli at humidities less than 60% in normal occupied rooms. The distribution factor varies with uniformity of lethal exposure of the organisms circulating through non-uniformly distributed radiation. Experience has shown that disinfection is sufficient if 150 cubic foot lethes

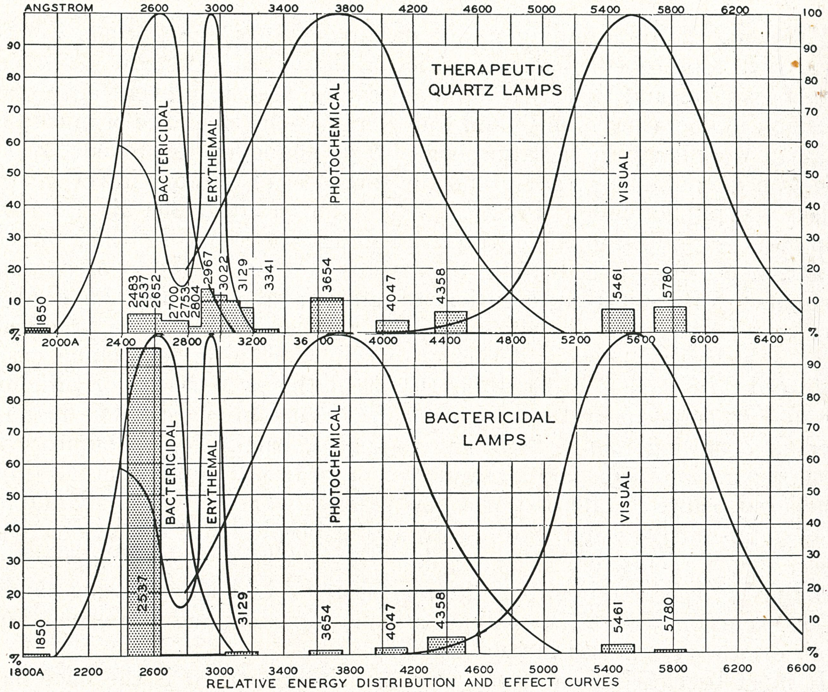


Fig. 245.—Relative energy distribution for equal electric inputs to hot quartz lamps and low-pressure bactericidal lamps with superimposed effect curves. (General Electric Co., Nela Park Division.)

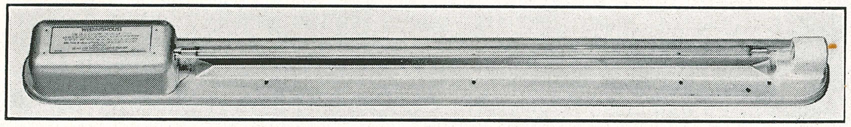


Fig. 246.—Sterilamp unit. (Courtesy Westinghouse Electric Corp.)

of disinfection, equivalent to 150 cubic feet of ventilation with pure air, per foot watt-minute of irradiation are obtained.

Testing and Care of Lamps.—When first installed, the radiant ultraviolet energy is considerably more intense than the minimum intensity for acceptance. As the lamps age, the intensity drops off rapidly at first and slower later. Under ordinary usage the lamps maintain the acceptable minimum intensity or above for the guaranteed period of 4000 hours of continuous operation. Users of the equipment are advised to test the lamps each month to determine that they are up to standard. Since the lamps burn at a characteristic color constantly, there is no way of determining whether they are emitting sufficient ultraviolet radiation except by testing them with an ultraviolet meter.

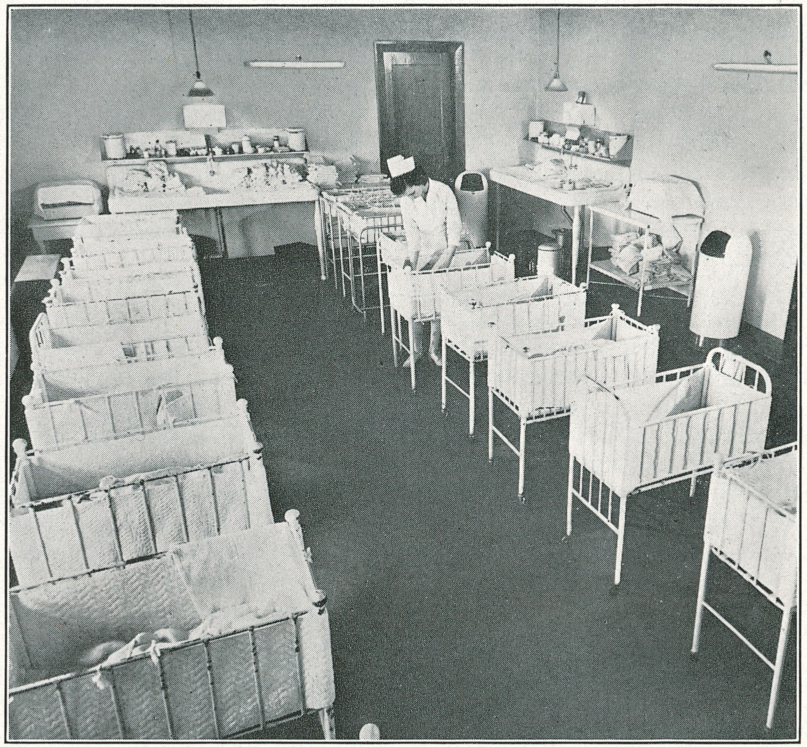


Fig. 247.—Germicidal lamp installation in children's ward. (Courtesy of Hanovia Chem. and Mfg. Co.)

Discharge tubes of lamps should be kept clean, since dust would absorb appreciable amounts of ultraviolet radiation. This should be done by wiping them frequently with a clean cloth moistened with pure residue-free absolute alcohol, carbon tetrachloride or distilled water.

Precautions.—Safe and efficient installation of germicidal units requires expert advice and sound engineering. Observations indicate that rays reflected from the lamp reflector or from walls or floors may be sufficient under certain conditions to cause conjunctivitis. Hence the total amount of direct and scattered ultraviolet radiation incident on the occupants must be kept below the level that will produce conjunctivitis, erythema and any